AMENDMENT(S) TO THE SPECIFICATION

Please insert the following new section beginning at page 1, after the title:

CROSS-REFERENCE TO RELATED APPLICATION

This application is based on and claims priority to patent application Serial No. 09/656,799, filed September 7, 2000 entitled RAPID DEPTH SCANNING OPTICAL IMAGING DEVICE, the entire contents of which are incorporated herein by reference.

Please replace the paragraph beginning at page 6, line 1, with the following rewritten paragraph:

However, for rapidly displacing a galvanometer mirror or the like, it is necessary to drive the galvanometer mirror with a voltage proportional to the sine of an angle of displacement. In this case, the Doppler shift occurs at a rate proportional to the cosine of the angle of displacement that is regarded as the derivative of the Doppler shift to the angle of displacement. Moreover, a heterodyne frequency to be detected varies. Consequently, the signal-to-noise ratio is degraded. Otherwise, since [[the]] light [[little]] undergoing [[the]] little Doppler shift is detected, the efficiency in detection is deteriorated.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an optical imaging device having a rapid reference scanning means that offers a high signal-to-noise ration and ~~enabling~~ enables realization of an inexpensive interferometer.

Please delete the paragraph beginning at page 8, line 1:

~~Over the second light path member, the low coherent light branched by the optical branching unit is routed.~~

Please replace the paragraph beginning at page 21, line 24, with the following rewritten paragraph:

Light emmanating from the low coherent light source 1 is routed to the first SM optical fiber 2, and branched into the second SM optical fiber 4 and fifth SM optical fiber 21a by the

optical coupler 3. Light routed to the ~~third~~ fifth SM optical fiber [[5]] 21a is propagated to the optical scanner probe 20 via the scanning means 19. Part of light reflected from a living tissue returns to the optical scanner probe 20, and passes through the scanning means 19 over the fifth SM optical fiber 21a. The light is then branched by the optial coupler 3 and routed to the third SM optical fiber 5.

Please replace the paragraph beginning at page 24, line 12, with the following rewritten paragraph:

The optical length variation optical system [[31]] 9 employed in an optical imaging device of the present embodiment that is realized as an optical tomography structure observation device consists mainly of, as shown in Fig. 3, a light introduction block h3, a pair of a first diffraction grating h4 and first positive lens h5, a wedged prism h6, a pair of a second positive lens h7 and a second diffraction grating h8, and a light pickup block h11. The light introduction block h3 is composed of the incidence SM optical fiber 8 and a third positive lens h2 offering a positive power. The first diffraction grating h4 serves as a spectrum dispersion element for spatially dispersing the spectrum of light. The first positive lens h5 offers a positive power. The wedged prism h6 serves as a phase modulation element for substantially linearly changing the phases of the angular frequency components of light dispersed by the spectrum dispersion element. The second positive lens h7 serves as a spectrum reuniting element for reuniting the phase-modulated angular frequency components of the spatially dispersed light into single light, and offers a positive power. The fourth positive lens h9 offers a positive power. These optical elements are optically interconnected.

Please replace the paragraph beginning at page 44, line 22, with the following rewritten paragraph:

The means for rotating the wedged prism h6 is not limited to the structure shown in Fig. 8 but may be structured as shown in Fig. 9. Specifically, as shown in Fig. 9, the wedged prism h6 may be held and locked in an inner ring 59 of a hollowed brushless motor. The motor consists of the inner ring 59, the housing 62, a permanent magnet 61 embedded in the inner ring 59, a coil 63 embedded in the housing 62, and bearings 60a and 60b for holding the inner ring 59 so that the inner ring 59 can rotate freely relative to the housing 62. When the motor is rotated, the

wedged prism h6 is rotated about the axis of rotation 47 of the motor. A compact magnet that is not shown may be embedded in the inner ring of the motor and a Hall element that is not shown may be opposed to the compact magnet, whereby an encoder may be constructed to control the rotating speed. Moreover, the sheet interceptor 58 and ~~photocoupler~~ photo-interrupter 54 shown in Fig. 8 or a pattern of shades formed on the inner ring and a reflection type photo-interrupted for detecting the pattern may be used to detect the home position of the wedged prism h6.

Please replace the paragraph beginning at page 52, line 1, with the following rewritten paragraph:

When the two cone lenses h12 and h13 are located mutually closely, light incident on surface A (or surface B) impinges on surface C (or surface D). Light getting out of the second cone lens h13 is not parallel to the light incident on the first cone lens h12, and will therefore not fall on the emission SM optical fiber 10. However, when the two cone lenses h12 and h13 are separated from each other, light incident on surface A (or surface B) passes through surface D (or surface C). When the two cone lenses h12 and h13 are separated from each other by a predetermined distance, light getting out of the cone lens [[2]] h13 becomes parallel to light incidence on the cone lens [[1]] h12. The light is then converged on the fourth positive lens h9 located behind the cone lens h13, and can therefore be gathered on the emission SM optical fiber 10.

Please replace the paragraph beginning at page 61, line 21, with the following rewritten paragraph:

Fig. 18A and Fig. 18B schematically show the arrangement of optical elements located behind the second diffraction grating [[8]] h8 included in an optical length variation optical system employed in the present embodiment. Fig. 18A shows the optical elements seen along the second axis, and Fig. 18B shows the optical elements seen along the first axis.

Please replace the paragraph beginning at page 84, line 3, with the following rewritten paragraph:

Fig. 31 shows the structure of a first variant of the ~~electrooptic~~ acoustooptic deflectors k43 and k47 serving as an optical scanning means and being shown in Fig. 27.

Please replace the paragraph beginning at page 85, line 3, with the following rewritten paragraph:

Fig. 32A to Fig. 32C show the structure of a hologram scanner k53 that is a second variant of the ~~electrooptic~~ acoustooptic deflectors k43 and k47. The hologram scanner k53 is, like the acoustooptic deflectors k43 and k47, an optical element for deflecting light.

Please replace the paragraph beginning at page 91, line 3, with the following rewritten paragraph:

Ninth Embodiment:

Fig. 38 shows the components of an optical length variation optical system employed in the ninth embodiment of the present invention. Differences from the optical length variation optical system [[9]] k67 shown in Fig. 35A will be described. The same reference numerals will be assigned to identical components, and the description of the components will be omitted.

Please replace the paragraph beginning at page 92, line 2, with the following rewritten paragraph:

Moreover, an optical block k80 may be unified with a rotary disk as shown in Fig. 40. The optical block k81 is hit with light at a rate of two points per turn. Otherwise, a rotary disk k81 may be, as shown in Fig. 41, made by bonding optical blocks k82a to k82d that resemble the optical block [[k80]] k81 shown in Fig. 40.

Please replace the paragraph beginning at page 97, line 21, with the following rewritten paragraph:

(Constituent features and operations)

In the optical length variation optical system 9 employed in the present embodiment, light emitted from the incidence SM optical fiber 8 falls, as shown in Fig. [[48]] 45, on an acoustooptic element 193 after being collimated to be light of parallel rays 190 by a collimator lens 29. Rays of the light 190 having a small wavelength are diffracted by a small angle of diffraction by the acoustooptic element 193 and propagated along a light path 194a. In constrast, rays thereof having a large wavelength are diffracted by a large angle of diffraction thereby and propagated along a light path 194b. A lens 195 exhibits chromatic aberration, and part of the

lens 195 exhibiting especially intense a chromatic aberration and lying away from the optical axis is used to converge the light on the end 37 of the emission SM optical fiber 10.

The optical length for the rays having a short wavelength and traveling along the path [[191a]] 194a is different from that for the rays having a large wavelength and traveling along the path [[191b]] 194b. The optical length difference depends on the wavelength and an angle θ (with respect to a parth of a ray of light emanating from the light source which has the same wavelength as the center frequency of the light). The angle θ varies depending on the frequency of a driving voltage to be applied to the acoustooptic element. Consequently, a phase change that differs with the wavelength occurs, and a propagation time changes.

(Advantages)

As mentioned above, the present embodiment provides the same advantages as those of the first embodiment. In addition, the frequency of a ~~scanning~~ driving voltage to be applied to the acoustooptic element is as high as about megahertz. This enables rapid scanning. Moreover, the frequency of the driving voltage to be applied to the acoustooptic element may be set to the value of a heterodyne frequency of a demodulated signal.

Please replace the paragraph beginning at page 101, line 19, with the following rewritten paragraph:

Referring to Fig. 46, the optical coupler 6 consists mainly of collimator lenses 78a, 78b, and 78c, and a polarization beam splitter (hereinafter PBS) 79. The scanning means 19 consists mainly of a rotary mirror 88, a motor 89, and an encoder [[93]] 90. The scanning drive unit 22 is realized with a three-phase driver 102.

Please replace the paragraph beginning at page 105, line 1, with the following rewritten paragraph:

The motor 89 is a brushless dc motor and driven an controlled by the three-phase driver 102. The motor 89 and three-phase driver 102 are connected to each other over three pairs of driving cables 98a and 98b, 99a and 99b, and 100a and 100b. Each pair of driving cables is spliced to each other at the connector 82. The encoder [[93]] 90 and three-phase driver 102 are linked by a pair of signal cables 101a and 101b. Signals of phases A, B, and Z (one pulse per rotation) are placed on the signal cables. The three-phase driver causes the rotary mirror 88 to

rotate by one turn in response to a signal output from the encoder [[93]] 90, and outputs information of an angle of rotation at the same time. But for the encoder [[93]] 90, the rotation of the motor may be controlled based on three driving signals that are mutually different in phase. Even in this case, the rotary mirror can be rotated on a stable basis. The information of an angle of rotation of the motor is input to the computer 27 shown in Fig. 1.

Please replace the paragraph beginning at page 109, line 5, with the following rewritten paragraph:

Assume that the rotation of the rotary mirror 88 is stopped and the ~~delay line~~ optical length variation optical system 9 is used to change a propagation time. In this case, one-dimensional information of a lesion to which light is irradiated from the probe, that is, information concerning the depth direction of a lesion is acquired as an interfering signal. The lesion is rapidly scanned in the depth direction thereof by continuously rotating the rotary mirror 88. When the acquired information of the lesion is visualized circumferentially, an image 109 shown in Fig. 48 is produced. Straight lines extending radially from the center of a rotation O indicate the depth direction of a lesion, and the directions of the straight lines indicate the orientation of the rotary mirror 88.

Please replace the paragraph beginning at page 115, line 10, with the following rewritten paragraph:

(Constituent features and operations)

According to the present embodiment, the differences of the components shown in Fig. 52 from the components shown in Fig. [[7]] 46 are described below. First, the scanning means shown in Fig. 46 uses the motor 89, which is located in the distal part of a probe, to drive the rotary mirror 88, while the scanning means shown in Fig. 52 uses a rotation shaft 115 borne by a bearing 119 to drive the mirror. Moreover, the motor 89 and encoder 90 are disposed in a main unit of an optical imaging device but not in the distal part of the probe. The rotation of the motor 89 is conveyed to the rotation shaft 115 via a coupler receptable 112 and a coupler 111 through the conveyer pins. The coupler receptacle 112 is included in a detachable connector 110 as a portion to be coupled to the device. The coupler 111 is included in the detachable connector 110 as a portion to be coupled to the probe. The conveyer pins are attached to the coupler 111. The

coupler 111 is held freely rotationally in the detachable connector 110 by means of a bearing 113.

Secondly, in the components shown in Fig. 46, the rotary mirror 88 is opposed to the gradient index lens 85 and quarter-wave plate 86. In the components shown in Fig. 52, a rectangular prism 117 for turning a light path, a quarter-wave plate 86, a gradient index lenses 116a and 116b corresponding to two divisions of the gradient index lens 85 are included so that the gradient index lenses will be juxtaposed. The other components are identical to those shown in Fig. [[7]] 46.

Please replace the paragraph beginning at page 117, line 12, with the following rewritten paragraph:

Fourteenth Embodiment:

Fig. 53 to Fig. 55 are concerned with the ~~fourth~~ fourteenth embodiment of the present invention. Fig. 53 shows the structures of an optical scanner probe and a scanning means. Fig. 54 shows the structure of a variant of the scanning means shown in Fig. 53. Fig. 55 shows a gradient index lens, which is shown in Fig. 53 and Fig. 54, seen along the optical axis.

Please replace the paragraph beginning at page 120, line 17, with the following rewritten paragraph:

To be more specific as shown in Fig. 56, in an optical scanner probe employed in the present embodiment, the end of the first P optical fiber 80 is locked in a fiber joint 137 formed as an integral part of an advancement/withdrawal shaft 132. One end of the second PM optical fiber [[82]] 81 is locked in a ferrulse [[13B]] 138 opposed to the fiber joint 137. The fiber joint 137 and ferrule 138 are attachable or detachable and engaged with the cylindrical side wall. The angular relationship between the fiber joint and ferrule is maintained by a detent 139 and a detent receptor 140. The fiber joint 137 and ferrule 138 are attachable or detachable owing to mounting levers 141, claws 151, concave parts 152, and springs 143. The mounting levers 141 are attached to a coupling shaft 144 and can pivot with axes 142 as fulcra. The claws 151 are formed as distal parts of the mounting levers 141. The concave parts 152 are formed in the advancement/withdrawal shaft 132 and engaged with the claws 151. The mounting levers 141 are brought into contact with the advancement/withdrawal shaft 132 with the axes 142 as fulcra

by means of springs that are not shown. When the fiber joint 137 and ferrule 138 are joined, they are brought into contact with each other due to the resiliency of the springs 143. The first PM optical fiber 80 and second PM optical fiber [[82]] 81 are joined reliably while planes of polarization are maintained.

Please replace the paragraph beginning at page 123, line 2, with the following rewritten paragraph:

Moreover, the advancement/withdrawal shaft 132 can freely slide larerally in Fig. 56 owing to linear bearings 133 attached to the rotary ring 153 and V-shaped grooves 134 bored in the advancement/withdrawal shaft 132. Fig. [[20]] 57 shows the A-A cutting plane of the sliding unit.

Please replace the paragraph beginning at page 123, line 19, with the following rewritten paragraph:

The computer 27 sends a driving control signal to the linear driving stage 135. The movement of the linear driving stage 135 is conveyed to the advancement/withdrawal shaft 132 by way of the driving shaft 136 and bearings 131. The lateral movement of the advancement/withdrawal shaft 132 is conveyed to the ferrule 138, springs 143, mounting levers 141, coupling shaft 144, and flexible shaft 148. This finally causes a distal optical unit, which is composed of the lens frame 156, gradient index lens 85, quarter-wave plate 86, and prism 157, to move laterally. Consequently, observation light is irradiated in order to scan an object laterally. At the same time, the object is scanned in its depth direction owing to the ~~delay line~~ optical length variation optical system 9. Eventually, the object is visualized two-dimensionally, that is, in the depth direction and lateral direction.

Please replace the paragraph beginning at page 126, line 13, with the following rewritten paragraph:

Sixteenth Embodiment:

Fig. 58 to Fig. 62 are concerned with the ~~sixth~~ sixteenth embodiment. Fig. 58 shows the structure of a major portion of an optical imaging device. Fig. 59 is an explanatory of an optical imaging device. Fig. 59 is an explanatory diagram concerning the first variant of an optical

scanner probe shown in Fig. 58. Fig. 60 is an explanatory diagram concerning the second variant of the optical scanner probe shown in Fig. 58. Fig. 61 is an explanatory diagram concerning the third variant of the optical scanner probe shown in Fig. 58. Fig. 62 is a sectional view showoing a cutting plane along the optical axis containing a stationary mirror shown in Fig. 61.

Please replace the paragraph beginning at page 127, line 15, with the following rewritten paragraph:

When the optical coupler 6 is employed, even in 100 % of light routed to the seventh SM optical fiber 160 returns, up to a quarter of light emitted from the third SM optical fiber 5 is propagated to the fourth SM optical fiber 13. In contrast, when the optical circulator 159 is employed, the efficiency in propagating return light to the fourth SM optical fiber can be improved to be [[a]] double or more.

Please replace the paragraph beginning at page 130, line 25, with the following rewritten paragraph:

The detailed structure of a radial scan type probe has been disclosed in the patent publication No. WO97/32182 ~~Wo97/32182~~. A distal optical system composed of a lens frame, a gradient index lens, a prism, and other elements is disposed in the distal part of the probe. It is therefore hard to design the probe compactly, though a compact probe is highly ~~requested~~ needed for such a usage [[that]] there the probe is inserted in a small-diameter endoscope or for studies of alimentary organs or blood vessels. Besides, assembling and adjustment is very complex and requires many man-hours. Moreover, in the disclosed structure, light reflection occurs at a joint between an emission end of an optical fiber and a lens or between a lens and a prism. This leads to a deteriorated signal-to-noise ratio.

Please replace the paragraph beginning at page 138, line 16, with the following rewritten paragraph:

The light returned to the ninth SM optical fiber 207a and the light returned to the tenth SM optical fiber 207b are multiplexed by the WDM 203b and propagated over the eighth SM optical fiber [[286]] 206. Light emitted from the eighth SM optical fiber [[286]] 206 to the collimator lens 78b is converted from circularly polarized light ot linearly polarized light that

vibrates vertically to the sheet of the drawing by means of the ~~1/4 wave~~ quarter-wave plate 86. The PBS 79 highly efficiently reflects the linearly polarized light towards the collimator lens 78c. The light is then propagated over the emission SM optical fiber 10. The optical branching unit 204 highly efficiently routes light emitted from the incidence SM optical fiber 8 to the delay line unit 20 owing to the foregoing optical elements. Moreover, the optical branching unit 204 routes light returned from the delay line unit 205 to the emission SM optical fiber 10.

Please replace the paragraph beginning at page 140, line 18, with the following rewritten paragraph:

The optical coupler 14 causes light returned from the optical scanner probe 20 and light returned from the delay line unit 205 to interfere with each other. The detectors [[7]] 17 and 18 and differential amplifier 23 convert an interfering signal, which is modulated based on a hereodyne frequency, into an electric signal. The light whose wavelength corresponds to the center wavelength $\lambda 1$ and the light whose wavelength corresponds to the center wavelength $\lambda 2$ have different heterodyne frequencies that depend on the settings of the first delay line 262a and second delay line 262b respectively included in the delay line unit 205. Demodulators 212a and 212b formed with bandpass filters whose transmission bands contain the heterodyne frequencies or lock-in detectors detect frequency components having the same frequencies as the heterodyne frequencies. The outputs of the demodulators 212a and 212b are fed to the computer 27 via the A/D converters 25.